



TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Ground Vehicle CFD at TARDEC

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- TARDEC/CASSI Introduction
- Why TARDEC Performs Simulation
- Examples of typical CFD problems
- New CRES Program
- Questions

TARDEC - Tank Automotive Research, Development and Engineering Center

- Develops, integrates, and sustains technology for all manned and unmanned DOD ground systems
- R&D for ground systems integration and technology

What We Do

- Provide information to make acquisition decisions
- $\frac{2}{3}$ of Engineers are embedded support to programs
- $\frac{1}{3}$ of Engineers are performing cutting edge R&D
- Modeling and simulation, including HPC processes are core to acquisition support



Fuel Efficiency Demonstrator



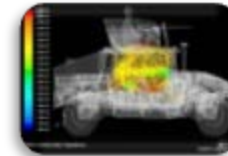
We support a diverse set of product lines through their life cycles, from combat and tactical vehicles, watercraft, to fuel and water distribution equipment.

System-centric Modeling and Simulation to integrate and assess the impacts of new concepts/technologies and changes to existing systems.

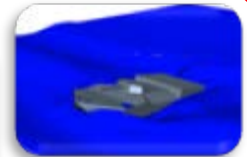
Concepts
Analysis
Systems
Simulation
Integration



Dynamics and Durability



Thermal / CFD/ Acoustics



TARDEC HPC

Unclassified

- 512 Node Unclassified
- 6 TFlops

Classified

- 768 Node Classified: 9 TFlops
- Infiniband Interconnects

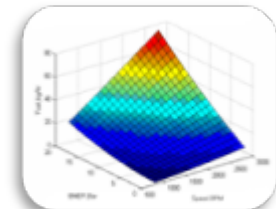
..... DOD HPC Centers



Energetic Effects and Crew Safety

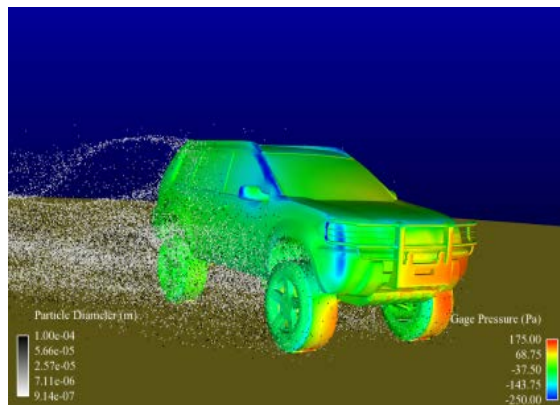


Powertrain / Operational Energy



Data Analysis and Multidisciplinary Optimization

- Why TARDEC uses mainly commercial codes
 - Build a repository of vehicle models
 - Reuse of models for multiple purposes
 - Mesh wrapping capabilities shave weeks off the pre-processing time
- Issue: Scalability
 - Even w/ Infiniband, scale to 200,000 elements per node up to around 32 nodes.
 - Beyond 32 nodes, communications starts to dominate
 - Typical 16 million cell models we only use 64 nodes
 - Dust modeling, fire suppression, blast solid modeling have particular scaling problems because of the use of Lagrangian particles



Example: Dust modeling for engine durability does not scale on commercial code!

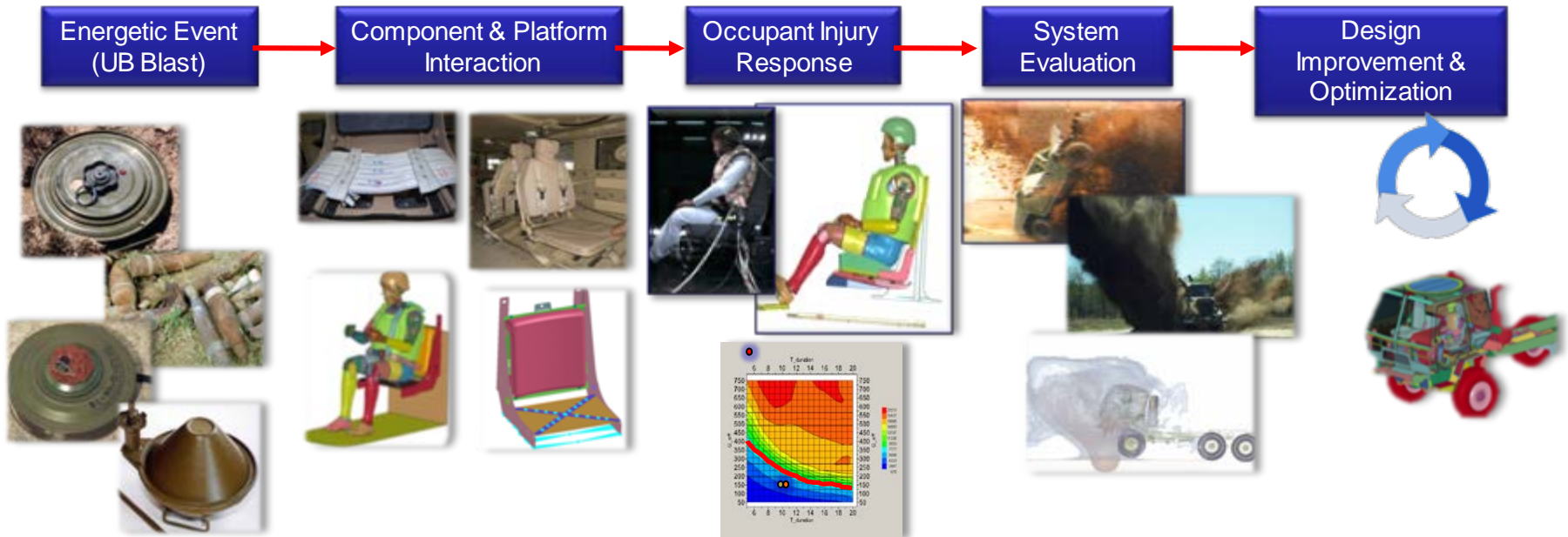
Given - contractors design and build vehicles...

Why does the government do CAE?



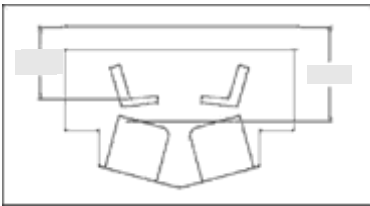
- Pre-Request For Proposal (RFP) work
 - Need to ensure specifications are technically feasible before issuing RFPs
 - Analysis of Alternatives (AOA) studies
- Evaluation of proposals and oversight of supplier efforts
 - ‘Honest Broker’ - proposed solutions should be evaluated on a level playing field
 - Verify supplier analyses are reasonable
- Rapid response for field fixes
 - Determine how new equipment will affect vehicle performance
 - Provide initial assessment before starting formal contract process for proposed upgrades
- Analysis for technology demonstrator vehicles

- Underbody mine blast
- HVAC design / interior cooling
- Propulsion cooling
- Fire suppression modeling
- Thermal Effectiveness modeling
- Amphibious operation
- Physical testing support



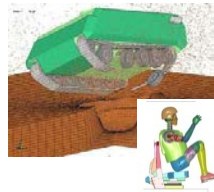
Use commercial automotive crash simulation models for blast

Packaging / CAD



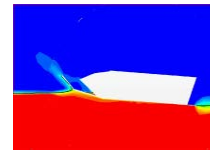
- Packaging studies
- Weight and CG tracking (key)
- Crew location (seat stroke)
- Propulsion/ waterjet locations
- Technology survey
- Level 2 drawings

Blast Full-Vehicle Analysis



- Soil, structure, and crew
- Optimize materials, ride height, and structure

CFD Water Mobility

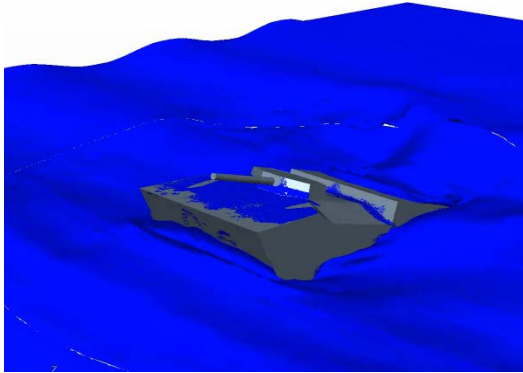


- Required thrust
- Resistance optimization
- Reserve buoyancy
- Sea stability

Land Mobility / Automotive Performance Analysis



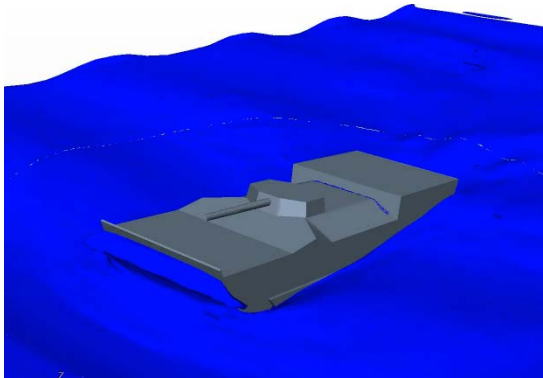
- Stress/ fatigue analysis
- Mobility
- Propulsion analysis
- Suspension optimization



Baseline

0% increase in volume

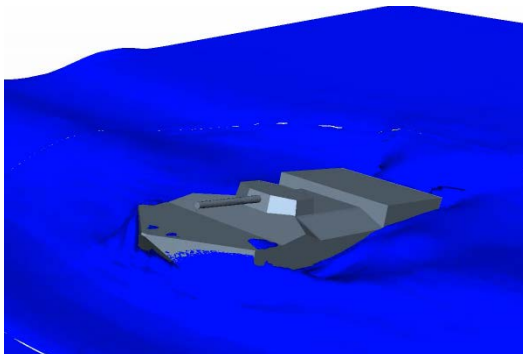
0% improvement in resistance



Shape I

10.8% increase in volume

28.2% improvement in resistance



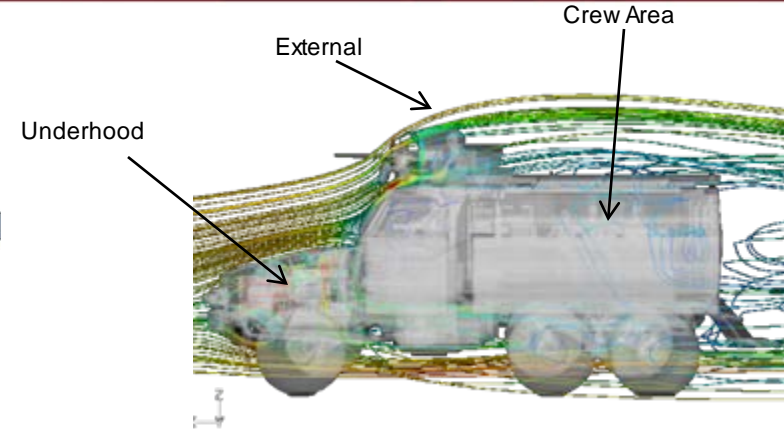
Shape II

8.7% increase in volume

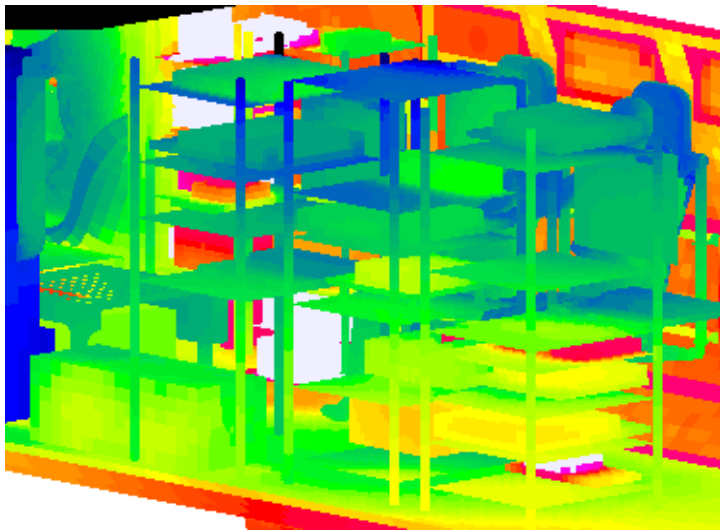
12.9% improvement in resistance



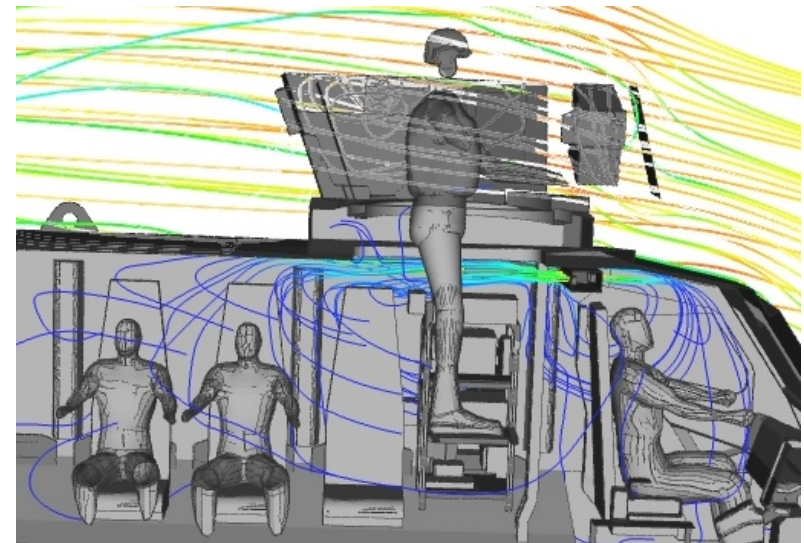
HVAC Duct Design/ Cooldown Sizing



Exterior Flow Field



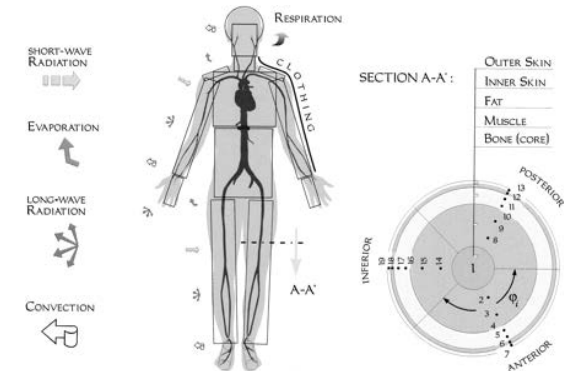
Component Temperatures



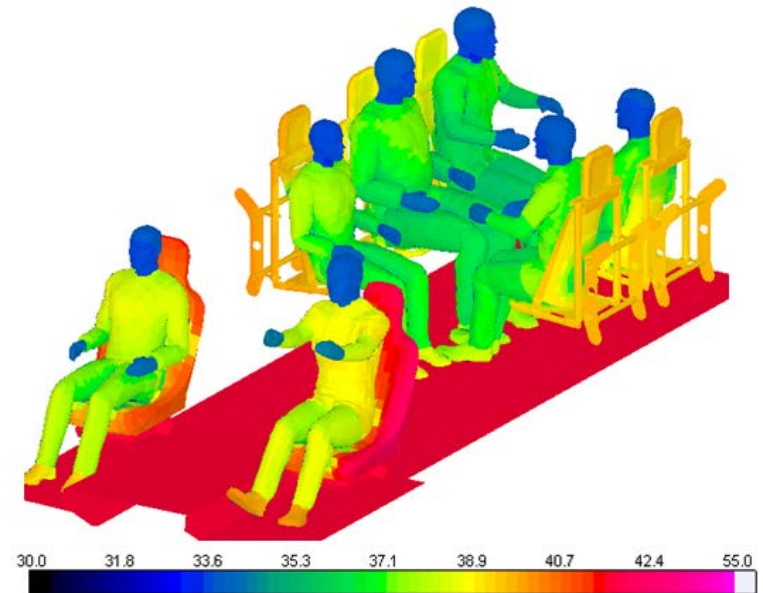
Simulation: Hatch Open

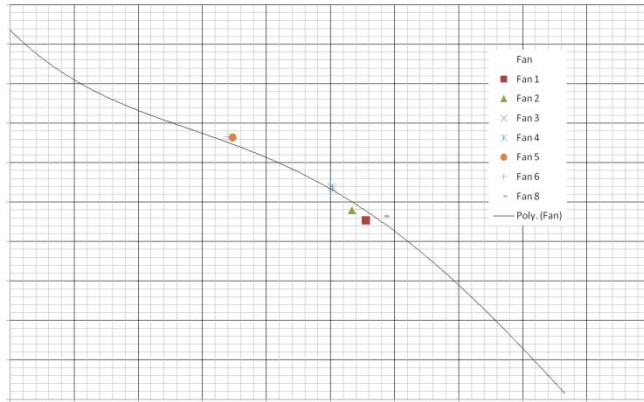
Objective:

- Assess crew's ability to perform mission based on interior environment CFD
 - Based on Fiala's Physiology Model
 - 20 body segments
 - with 4 to 5 tissue layers per segment
 - Define metabolic heat rates by role (driver, gunner, commander)
 - Shivering
 - Respiration
 - Sweating
 - Peripheral Vasomotion
 - Sweating, clothing, etc all accounted

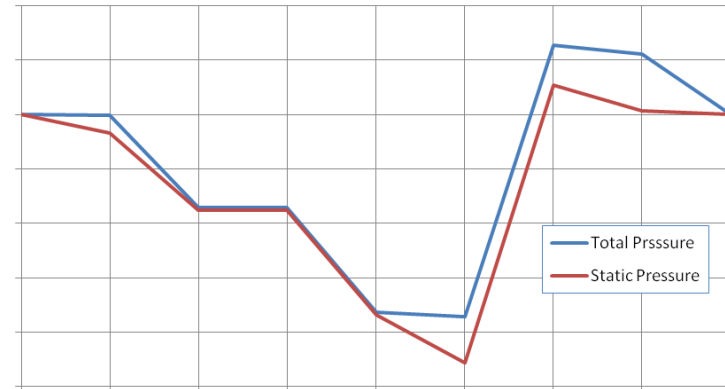


Shown: Various physiological builds (ranging from 5th Percentile to 95th Percentile)

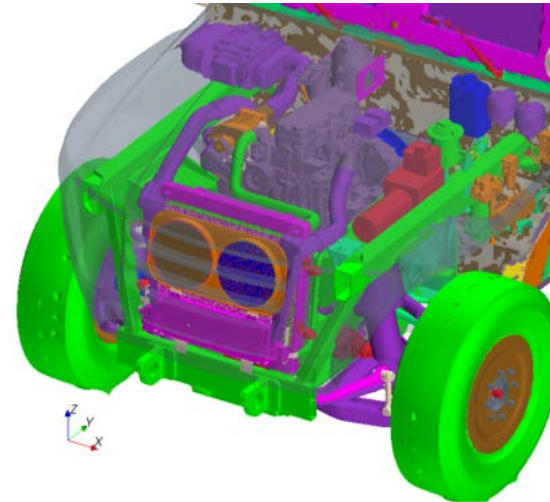
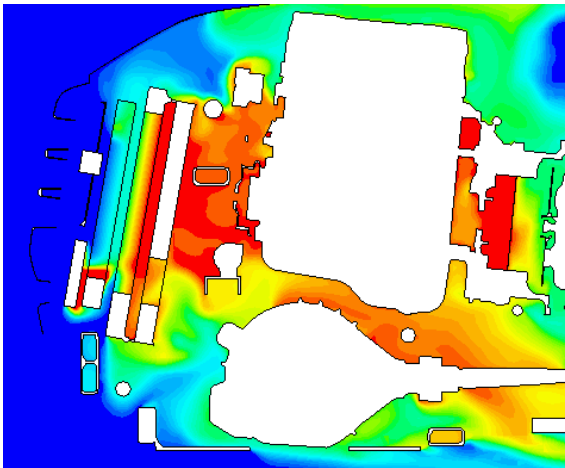




Fan Operating Points/Power Prediction

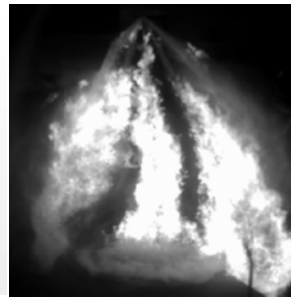
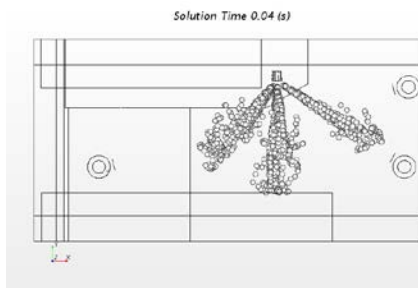
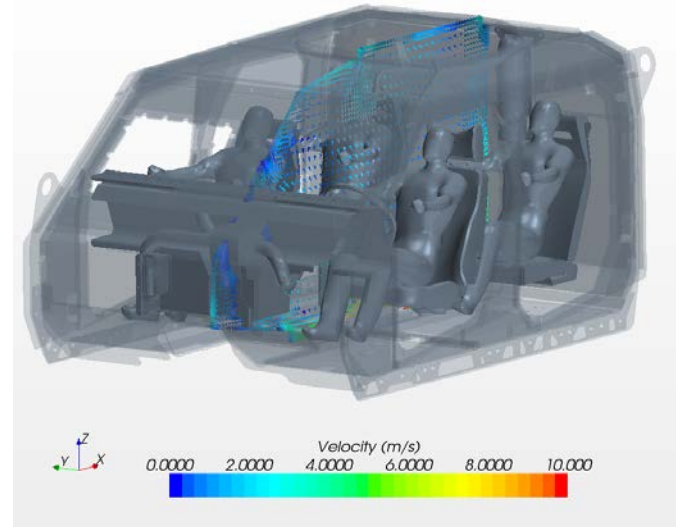


Pressure Trace Through System

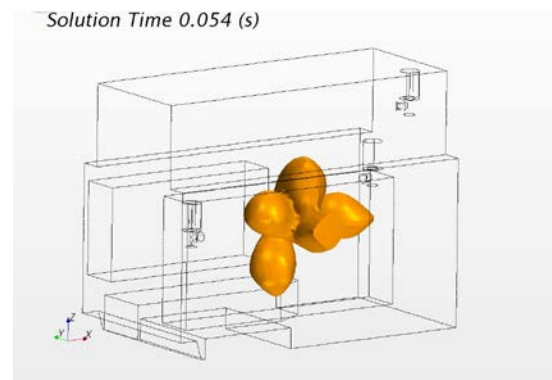


- **Types of suppressants**
 - Evaporating liquid or liquid+solid
- **Challenges**
 - Multiphase + Lagrangian particles
 - Combustion (~9 reaction steps)
 - Initial fireball
 - Suppression chemistry
 - Soot radiation
 - Evaporation of droplets
 - Droplet interaction with wall
 - Droplet/ droplet collision

Leverage HVAC model (non-static air)



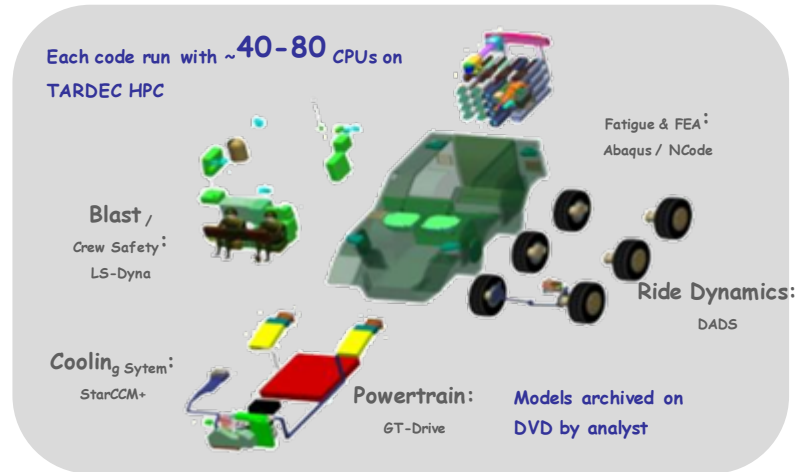
Example: Testbed Fireball Generation - 10 Hole Showerhead



Iso-surface of Temperature 800K, FM200 Parcels

- Traditional analysis evaluates a specific design for a specific performance objective for each discipline.
 - TARDEC using commercial codes, which don't scale up to real HPC capacity
 - Large commercial software budget
 - 2-3 month turn around

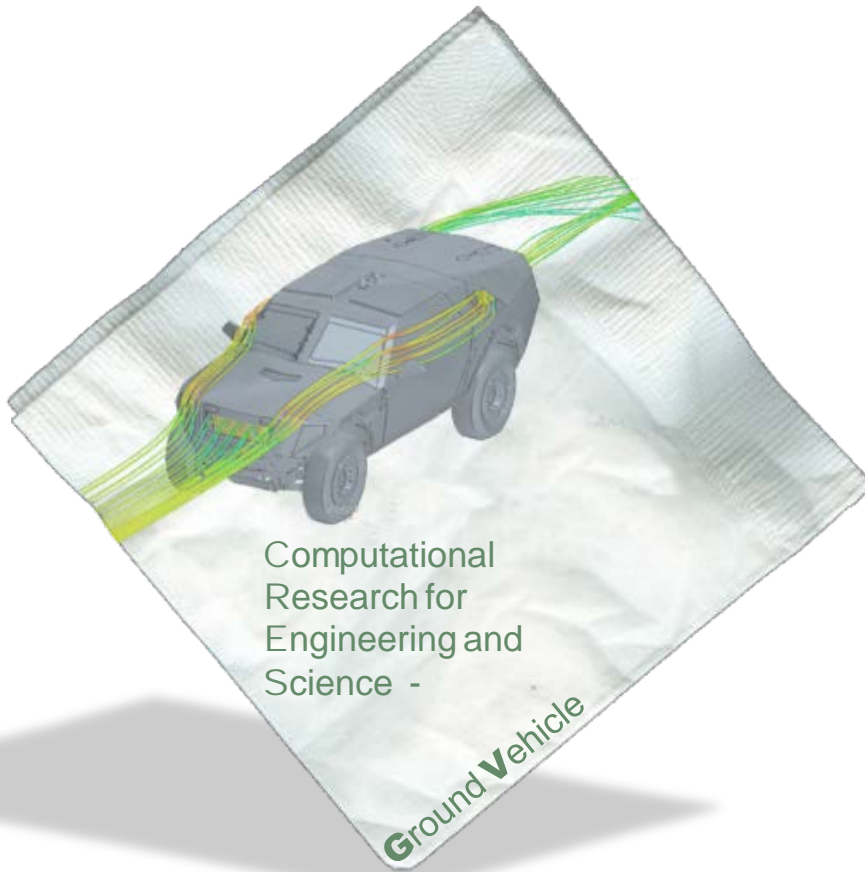
Example project using TARDEC non-integrated commercial CAE tools



- Systems engineering trade-offs made with limited knowledge
 - Limited set of design space explored
 - As an example, force-on-force models use best available performance data
 - User/vehicle interface not physically evaluated until demonstrator vehicles
- OEMs and TARDEC do design on individual workstations and sometimes TARDEC runs on its own HPC cluster

- Government doesn't usually own the Technical Design Package
 - Geometry sources from best available
 - CAD
 - Scans
 - Hand measurements
 - Occasionally CAE which needs to be translated
 - Material properties often from measurements, etc
 - Run engines on a dyno to obtain the fuel maps
 - High strain-rate materials measurement for blast
 - Installed equipment from many sources
 - Literally many components are "black boxes"

Goal: Provide Integrated Up-Front M&S Tools and Accelerate Process for Ground Vehicle Acquisition Support



- New program starting in HPC Modernization Office
- Commercial-Quality Government Owned Software

1. Fast Multidisciplinary Physics Solver Suite

- Fast answer with less model preparation
- Near realtime?

2. Optimization Tool

- Focus on robustness optimization, not point solution

3. High-Level Systems Tradespace Tool

4. Concept Definition Tool

- Goal: Computer aided brainstorming w/ physics and interface to models
- Start with CREATE Capstone - add Back-of-Napkin 3-D sketching
- Creativity and effectiveness depends on the whole design loop

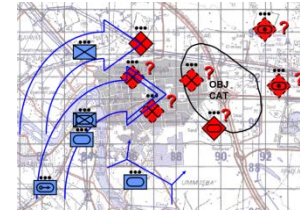
5. Improved Soldier-in-the-loop "Try it Before You Buy It"



Goal: Knowledge Based Acquisition

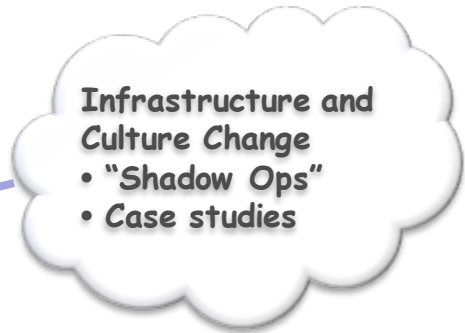


Physics Based = Better Informed Requirements



Operational Models based on accurate data

Ground Vehicle CRES



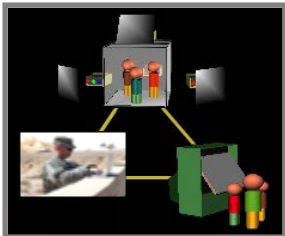
Quick Turnaround Model Based

Engineering

Soldier-in-the-loop

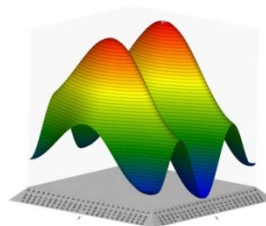
- Duty Cycle Characterization
- Key to Soldier Centric Design

Faster Concepting / Design Collaboration



- BETTER Concepting CAD "3-D Back of the napkin"
- Users co-design with physics-based feedback

Better Designspace Exploration



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- CFD modeling at TARDEC is done using commercial codes
 - Scalability issues
- Problems are usually very multidisciplinary
- Reuse the models a lot
- Large challenges in getting data
- New CRES-GV program looking into how to improve the vehicles that wind up in soldiers hands

THANK YOU

Questions?

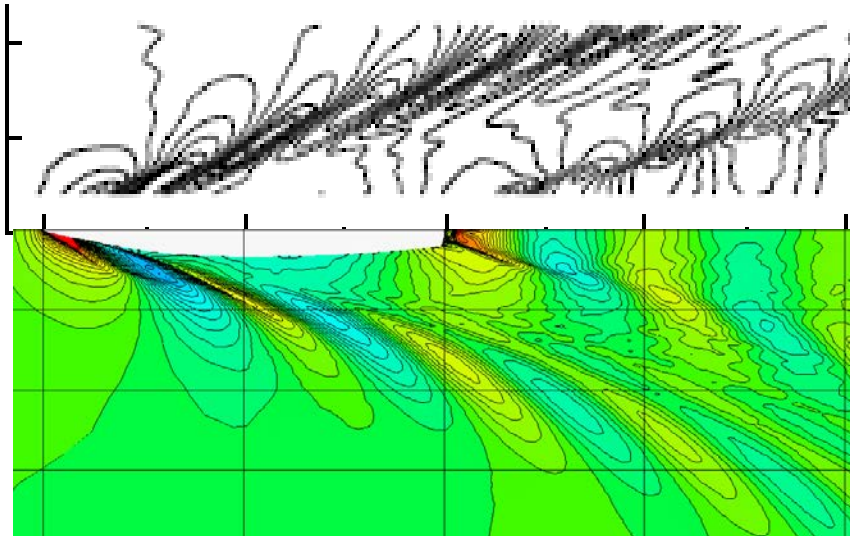
Tow Tank Model



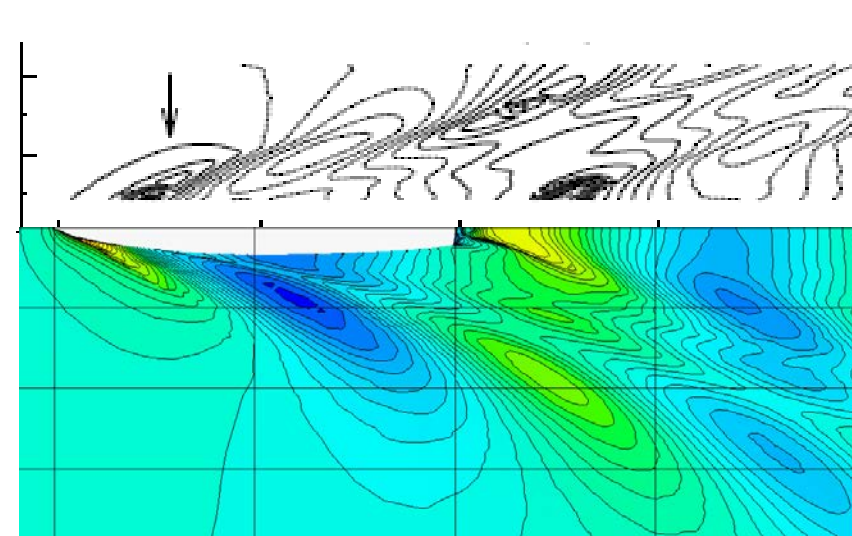
Resistance

| Model Speed | | | Resistance (N) | | |
|-------------|-------|-------|----------------|-----|--------|
| Fr | Knots | m/s | Test | CFD | Error |
| 0.280 | 4.076 | 2.097 | 45.14 | 45 | -0.32% |
| 0.410 | 5.970 | 3.071 | 152.60 | 150 | -1.70% |

Wave height contours at 2.097 m/s ($Fr=0.280$)



Wave height contours at 5.97 m/s ($Fr=0.410$)



Data from: A. Olivieri, F. Pistani, A. Avanzini, F. Stern, R. Penna. 2001.

"Towing Tank Experiments of Resistance, Sinkage and Trim, Boundary Layer, Wake, and Free Surface Flow Around a Naval Combatant INSEAN 2340 Model"

IHR Technical Report No. 421